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(54) [Title of the Invention]

Organic electric field light emission panel

(57) [Abstract]

[Structure]

An organic electric field light emission panel having, on a substrate, an organic electric field light emitting element constituted of an organic light emitting layer sandwiched between an anode and a cathode, and an active matrix circuit for driving the organic electric field light emitting element, in which the active matrix circuit is constituted of a first thin film transistor which is turned on in response to a switching signal and charges and discharges an accumulating capacitor in response to a light emission signal, and a second thin film transistor which is turned on and off in response to a discharge voltage of the accumulating capacitor thereby controlling a light emission and a light non-emission of the organic electric field light emitting element.

[Effect]

An active matrix circuit constituted of thin film transistors and a capacitor is provided on a same substrate as that for the organic electric field light emitting element to realize an organic electric field light emission panel of an excellent display ability.

[Claims]

[Claim 1]

An organic electric field light emission panel characterized in including, on a substrate, an organic electric field light emitting element constituted of an organic light emitting layer sandwiched between an anode and a cathode, and an active matrix circuit for driving the organic electric field light emitting element, wherein said active matrix circuit is constituted of a first thin film transistor which is turned on in response to a switching signal and charges and discharges an accumulating capacitor in response to a light emission signal, and a second thin film transistor which is turned on and off in response to a discharge voltage from said accumulating capacitor thereby controlling a light emission and a light non-emission of said organic electric field light emitting element.

[Detailed Description of the Invention]

[0001]

[Industrial field of application]

The present invention relates to an organic electric field light emission panel, and more particularly to a thin film device which emits light by applying an electric field to a light emitting layer formed by an organic compound.

[0002]

[Prior Technology]

Conventionally, an electric field light emitting element of thin film type has generally been prepared by doping an inorganic II-VI group compound semiconductor such as ZnS, CaS or SrS with Mn or a rare earth element (Eu, Ce, Tb, Sm etc.) as a light emitting center, but such electric field light emitting element prepared with the aforementioned inorganic material is associated with drawbacks of 1) requiring an AC drive (50 - 1000 Hz), 2) a high drive voltage (about 200 V), 3) difficulty in achieving full colors (particularly difficult to obtain blue color), and 4) a high cost of a peripheral drive circuit.

[0003]

However, in order to resolve the aforementioned drawbacks, developments are recently made for an electric field light emitting element utilizing an organic thin film. Particularly an electric field light emitting element which optimizes the type of the electrodes for improving a carrier injection efficiency from the electrodes for increasing the light emission efficiency and which employs an organic positive

hole transport layer formed by an aromatic diamine and a light emission layer constituted of an aluminum complex of 8-hydroxyquinoline (for example Appl. Phys. Lett., 51, p. 913 (1987)) achieves a significant improvement in the light emission efficiency, in comparison with a prior electric field light emitting element utilizing a single crystal of anthracene etc.

[0004]

**[Problem to be solved by the Invention]**

In case of utilizing such organic electric field light emitting element in a display panel, there is generally employed a matrix address method (cf. JP-A-2-66873, Institute for Electronics, Information and Communication Engineers, Technical Report OME89-46, 37, 1989 etc.), but, along with an increase in the number of pixels, a decrease in luminance corresponding to a decrease in the duty ratio (cf. Institute for Electronics, Information and Communication Engineers, Technical Report OME88-47, 35, 1988) and a crosstalk phenomenon constitute significant problems in the practice.

[0005]

In order to avoid the aforementioned drawbacks, it is conceivable to drive the organic field light emitting element with an active matrix circuit, but, in an already disclosed method (cf. JP-A-2-148687 etc.) in which each organic field light emitting element is connected to a memory device

constituted of plural MOS transistors for controlling the luminance with a digital signal, mounting of such circuits on a same substrate as that for the organic field light emitting element is very difficult as it reduces the aperture rate and requires a large number of wirings.

[0006]

In consideration of the foregoing, the present inventors are to provide an organic field light emission panel provided with an organic field light emitting element and an active matrix drive circuit therefor on a same substrate.

[0007]

[Means for Solving the Problems]

In essence, the present invention provides an organic field light emission panel characterized in including, on a substrate, an organic electric field light emitting element constituted of an organic light emitting layer sandwiched between an anode and a cathode, and an active matrix circuit for driving the organic electric field light emitting element, wherein the active matrix circuit is constituted of a first thin film transistor which is turned on in response to a switching signal and charges and discharges an accumulating capacitor in response to a light emission signal, and a second thin film transistor which is turned on and off in response to a discharge voltage from the accumulating capacitor thereby controlling a light emission and a light non-emission of the

organic electric field light emitting element.

[0008]

In the following, the organic field light emission panel of the present invention will be explained with reference to the accompanying drawings. Fig. 1 is a cross-sectional view schematically showing an example of the structure of an ordinary organic field light emitting element employed in the present invention, wherein shown are a substrate 1, an anode 2, a positive hole transport layer 3, a light emission layer 4 and a cathode 5. The substrate 1 constitutes a support member for the organic field light emitting element, and a plate of quartz or glass is used.

[0009]

On the substrate 1, there is provided an anode 2, which is generally constituted of a metal such as gold, silver, palladium or platinum, a metal oxide such as an indium and/or tin oxide (hereinafter represented as ITO), copper iodide, or a conductive polymer such as poly(3-methylthiophene). A compound to be employed in the positive hole transport layer 3 provided on the anode 2 can be, for example, an aromatic amine compound such as N,N'-diphenyl-N,N'-(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine; 1,1'-bis(4-di-p-tolylaminophenyl)cyclohexane; or 4,4'-bis(diphenylamino)quadrophenyl described in JP-A-59-194393 and USP No. 4,175,960, a hydrazone compound described in

JP-A-2-311591 or a silazane compound described in USP No. 4,950,950. These compounds may be used singly, or, if necessary, in a mixture. In addition to the foregoing compounds, there can be employed a polymer material such as polyvinylcarbazole or polysilane (Appl. Phys. Lett., 59, 2760, 1991).

[0010]

A material to be employed in the light emission layer 4 can be an aromatic compound such as tetraphenylbutadiene (JP-A-57-51781), a metal complex such as an aluminum complex of 8-hydroxyquinoline (JP-A-59-194393), a cyclopentadiene derivative (JP-A-2-289675), a perinone derivative (JP-A-2-289676), an oxadiazole derivative (JP-A-2-216791), a bisstyrylbenzene derivative (JP-A-1-245087 and JP-A-2-222484), a perylene derivative (JP-A-2-189890 and JP-A-3-791), a coumarine compound (JP-A-2-191694 and JP-A-3-792), a rare earth complex (JP-A-1-256584), distyrylpyrazine derivative (JP-A-2-252793), a p-phenylene compound (JP-A-3-33183), a thiadiazolopyridine derivative (JP-A-3-37292), a pyrrolopyridine derivative (JP-A-3-37293), a naphthylidine derivative (JP-A-3-203982) etc.

[0011]

The cathode 5 serves to inject electrons into the light emission layer 4. A material to be employed in the cathode 5 is preferably a metal of a low work function, in order to

efficiently inject electrons, for example a suitable metal such as tin, magnesium, indium, aluminum or silver or an alloy thereof. In addition to the structure shown in Fig. 1, organic field light emitting elements of following layer structures may be employed in the organic field light emission panel of the present invention.

[0012]

[Table 1]

anode/organic light emission layer/cathode

anode/organic light emission layer constituted of polymer/cathode

anode/organic light emission layer dispersed in  
polymer/cathode

anode/positive hole transport layer/organic electron transporting light emission layer/cathode

anode/organic positive hole transporting light emission layer/organic electron transport layer/cathode

anode/positive hole transport layer/organic electron transporting light emission layer/electron transport layer/cathode

In the following, there will be explained an active matrix circuit for driving the organic field light emitting element in the present invention.

100131

The organic field light emission panel of the present

invention is of a type in which, in the pixels of the organic field light emitting elements arranged in an X-Y matrix, one line each is selected in the X-direction while display signals for the pixels are given from electrodes in the Y-direction, and a selection signal in the X-direction is activated for each line and shifted over a cycle to perform a display on an entire image area. In such panel, a memory function is given to the circuit of each pixel. This is because, different from the case of liquid crystal, in case a current is given only in a selected state (a state for a pixel where a scanning electrode is turned on and a display signal is given), the pixel emits light only in such selected moment and a continuous display cannot be obtained on the entire image area. In the circuit, therefore, a memory is required in order to maintain a display state from a selected state to a next selected state after a cycle of the image area. Also there is employed a circuit enabling a current drive. More specifically, in comparison with a drive circuit for a liquid crystal, a current density in the element is 1000 times or more.

[0014]

Fundamental functions of the circuit have been explained in the foregoing, but, as display panel, a sufficiently large contrast, a large aperture rate of the image and absence of a crosstalk are also taken in consideration. Fig. 2 shows an active matrix drive circuit for a pixel, formed by thin film

transistors (TFT) and a capacitor. This circuit is constituted, for each pixel, of two TFTs and a capacitor, thereby realizing a current drive and a memory property. It has two electrodes (SCAN electrode and DATA electrode) for drive signals, thus being similar to that for liquid crystal, but is different in having a COM electrode for current supply, which is constantly given a voltage.

[0015]

In the following, functions of the element will be explained. In the circuit diagram in Fig. 2, TFT is represented as an FET, but TFT basically has a structure and a function similar to those of a MOS-FET, and can execute a switching operation between a source electrode and a drain electrode by a gate potential. Driving signals are so given as to select a line each time and an ON or OFF signal is given to each pixel in the selected line. The SCAN electrode is used as the electrode for selection, and the DATA electrode is used for giving the signal. In a selected state where the SCAN signal (input signal to the SCAN electrode) is HIGH, a TFT1 assumes an ON state, whereby a potential of an intermediate electrode FE becomes HIGH or LOW respectively if the DATA signal is HIGH or LOW. Therefore, in case the DATA signal is HIGH, a TFT2 is turned ON to provide a HIGH output potential (potential of pixel electrode). Also, in case the DATA signal is LOW, the TFT2 is turned OFF to provide a LOW output potential. When

the SCAN signal is shifted to LOW, namely a non-selected state, the TFT1 is turned OFF but the potential of the intermediate electrode FE is retained by a capacitor C and does not change, so that the output potential state does not change when the DATA signal is changed. The output potential changes when the line including this pixel again assumes the selected state, namely when the SCAN signal becomes HIGH and a signal different from before is given to the DATA electrode. Such circuit enables a drive of active matrix type even in a current drive type.

[0016]

Fig. 3 shows the aforementioned circuit, realized on a substrate in consideration of the aperture rate. Fig. 4 shows a pattern of four circuits. A material for the TFT employed in the active matrix circuit of the present invention can be amorphous silicon (a-Si), polycrystalline silicon (poly-Si) or cadmium selenide (CdSe). As to the structure of TFT, there is preferably employed so-called inverse stagger structure.

[0017]

As a representative example, Fig. 4 shows an a-Si TFT of inverse stagger structure. The a-Si TFT is formed on a glass substrate 6. For a gate electrode 7, there is employed Mo, Ta, Al, Cr or laminated films or an alloy thereof. The gate electrode is usually formed by electron beam evaporation or sputtering. For a gate insulation film 8, a silicon nitride

film ( $\text{SiN}_x$ ) is employed, on which an I-type a-Si layer 9 and an n<sup>+</sup> type a-Si film 10 are laminated. The silicon nitride film ( $\text{SiN}_x$ ), the I-type a-Si layer and the n<sup>+</sup> type a-Si layer are usually formed in continuation by plasma CVD. After a window is formed in the n<sup>+</sup>-type a-Si film 10, source and drain electrodes 11a, 11b are formed. For the source and drain electrodes, there are employed metals similar to that for the gate electrode. In the aforementioned a-Si TFT, a charge is induced on the surface of the I-type a-Si semiconductor layer by the gate potential, and a switching operation between the source and drain electrodes is executed by presence/absence of such charge. The n<sup>+</sup>-type a-Si layer is a contact layer for achieving smooth charge transfer to the electrode.

[0018]

The capacitor and a crossing portion of electrodes are made of a structure utilizing the insulation film for the TFT and preparable simultaneous with the preparation of the TFT. The capacitor, being formed with the COM electrode of the constant potential, has a circuit configuration resistant to noises. An example of the producing process for the organic field light emission panel is shown in Fig. 5.

[0019]

[Table 2]

(a) lower electrode forming step: patterning of an ITO pixel electrode 12 and a gate electrode 7a (electrode 7b constituting

an electrode of the accumulating capacitor)

(b) a-Si continuous film forming step:  $\text{SiN}_x$  layer 8/I-type  
a-Si layer 9/n<sup>+</sup>-type a-Si layer 10

(c) a-Si patterning step: TFT (8a - 10a) and accumulating  
capacitor (8b - 10b)

(d) upper electrode forming step: formation of a source  
electrode and drain electrodes 11a, 11b of TFT, and electrode  
11c of the accumulating capacitor

(e) TFT channel formation: etching-off of n<sup>+</sup>-type a-Si layer  
10a

(f) organic light emission layer film forming step:  
formation of an organic light emission layer 13

(g) cathode forming step: formation of a cathode 5.

In the aforementioned process example, the final cathode  
formation can be a uniform film formation over the entire area,  
and a cathode pattern as in the already disclosed matrix  
structure is unnecessary. Therefore, after the formation of  
the organic light emission layer, a photolithographic process  
that causes a damage to the organic light emission layer need  
not be conducted, and the entire process can be simplified.

[0020]

[Example]

In the following, the present invention will be explained  
further by an example, but the present invention will not  
be limited by the following example as long as the concept of the

invention is not exceeded. In the following, an example of preparation of an organic field light emission panel is shown. The TFT elements were designed in the circuit diagram shown in Fig. 2, with a gate length of 20  $\mu\text{m}$  and a gate width of 100  $\mu\text{m}$  for the first TFT, a gate length of 20  $\mu\text{m}$  and a gate width of 600  $\mu\text{m}$  for the second TFT. There were selected a pixel area of 600  $\mu\text{m} \times$  600  $\mu\text{m}$ , a pixel pitch of 800  $\mu\text{m} \times$  800  $\mu\text{m}$  and an aperture rate of 56 %.

[0021]

In the following, each manufacturing step will be explained.

(a) Lower electrode forming step

On an alkali-free glass substrate (NA-40, manufactured by HOYA), ITO was sputtered with a thickness of 120 nm (sheet resistance ca. 20  $\Omega/\square$ ) and was subjected to a patterning of a pixel electrode (anode) by ordinary photolithographic technology and wet etching utilizing hydrochloric acid. Then ordinary photolithographic technology and electron beam evaporation were used to laminate an Al layer of 100 nm and a Cr layer of 50 nm in succession to form a gate electrode.

(b) a-Si continuous film forming step

The substrate prepared in the step (a) was set in a plasma CVD apparatus and subjected to a continuous film formation of a-Si layers under conditions shown in Table 1.

[0022]

[Table 3]

Table 1

| Film forming condition                  | (1)SiN <sub>x</sub> layer | (2)i-layer a-Si | (3)n <sup>+</sup> -layer a-Si |
|---|---------------------------|-----------------|-------------------------------|
| <gas flow rate>                         |                           |                 |                               |
| SiH <sub>4</sub>                        | 10                        | 20              | 10                            |
| NH <sub>3</sub>                         | 100                       | -               | -                             |
| H <sub>2</sub>                          | -                         | 20              | -                             |
| PH <sub>3</sub> /H <sub>2</sub> (0.1 %) | -                         | -               | 100                           |
| substrate temp. [°C]                    | 300                       | 280             | 280                           |
| pressure [Torr]                         | 0.25                      | 0.15            | 0.33                          |
| power density [W/cm <sup>2</sup> ]      | 0.14                      | 0.08            | 0.08                          |
| film thickness [nm]                     | 300                       | 100             | 50                            |

[0023]

## (c) a-Si patterning step

The substrate was taken from the aforementioned plasma CVD apparatus, and a-Si was patterned by ordinary photolithographic technology and plasma etching utilizing SF<sub>6</sub> gas.

## (d) Upper electrode forming step

Ordinary photolithographic technology and electron beam evaporation were used to laminate a Cr layer of 50 nm and an Al layer of 100 nm in succession to form drain and source electrodes.

(e) n<sup>+</sup> a-Si layer etch-off step

Ordinary photolithographic technology and plasma etching utilizing SF<sub>6</sub> gas were used to etch the n<sup>+</sup> a-Si layer thereby forming a channel.

## (f) Organic electric field light emission layer forming step

The drive circuit substrate processed up to the step (e) was ultrasonic washed with acetone, ultrasonic washed with

methanol, rinsed with purified water, dried in dry nitrogen and subjected to UV/ozone washing, and was placed in a vacuum evaporation apparatus with a contact mask for limiting an evaporating portion, and the interior of the apparatus was evacuated to  $2 \times 10^{-6}$  Torr or less with an oil diffusion pump. Thereafter, an organic electric field light emitting element of the structure shown in Fig. 1 was prepared.

[0024]

As an organic positive hole transport layer material, N,N'-diphenyl-N,N'-(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine represented by a following structural formula (H1):

[0025]

[chemical 1]

formula (H1)

[0026]

was placed in a ceramic crucible, and evaporation was executed by heating with a tantalum wire heater around the crucible. In this operation, the crucible temperature was controlled within a range of 160 - 170°C. The vacuum at the evaporation was  $2 \times 10^{-6}$  Torr, and a positive hole transport layer 3 of a thickness of 60 nm was formed with an evaporation time of 3 minutes and 20 seconds.

[0027]

Then, as the material of the light emission layer 4, an aluminum complex of 8-hydroxyquinoline Al(C<sub>6</sub>H<sub>5</sub>NO)<sub>3</sub>, represented

by a following structural formula (E1):

[0028]

[chemical 2]

formula (E1)

[0029]

was evaporated in a similar manner on the aforementioned positive hole transport layer 3. In this operation, the crucible temperature was controlled within a range of 230 - 270°C. The vacuum at the evaporation was  $2 \times 10^{-6}$  Torr, and the evaporation time was 3 minutes and 30 seconds, and the film thickness was 75 nm.

(g) Cathode forming step

Product of film formation in the step (f) was taken out from the vacuum evaporation apparatus, and was placed in another vacuum evaporation apparatus with a contact mask for limiting a cathode evaporating portion, and a magnesium-silver alloy cathode was evaporated by a binary simultaneous evaporation with a film thickness of 150 nm. The evaporation was carried out with a molybdenum boat, a vacuum of  $3 \times 10^{-6}$  Torr and an evaporation time of 4 minutes and 30 seconds to obtain a lustrous film. Magnesium and silver had an atomic ratio of 10:1.5.

<Drive characteristics of organic field light emission panel>

An evaluation of the characteristics of a-Si TFT of the

organic field light emission panel prepared in the aforementioned steps (a) - (g) provided a mobility ( $\mu$ FE) of  $0.5 \text{ cm}^2/\text{V}\cdot\text{sec}$  and a threshold value of 3 V.

[0030]

Then, in case a 1-line selection time of 0.2 msec and a cycle time of the selection state (field time) of 10 msec were selected as the input signal wave form, input wave forms of the SCAN signal, the DATA signal and the COM signal are shown in Fig. 6. The input signal voltage was selected as LOW = 0 V and HIGH = 36 V for the DATA signal and the SCAN signal, and 25 V for the COM signal. Such input signal wave form corresponds to a field frequency (image rewriting frequency) of 100 Hz in a display of 100 lines (corresponding to 2-divided drive of the image area), and such field frequency is sufficient for displaying a moving image and a still image. A voltage wave form of the pixel electrode is shown in Fig. 7. A slow downshift from ON to OFF is observed, but is not a problem in consideration of the current-voltage characteristics of the organic field light emitting element, and a light emission wave form from an actual organic field light emitting element shows a steep downshift, satisfactory for a display (Fig. 8). A similar measurement was carried out also for a case of input signals corresponding to 200 lines and a field frequency of 50 Hz and satisfactory operation characteristics were obtained.

{ 0031 }

### [Effect of the Invention]

In the present invention, by providing an active matrix circuit constituted of thin film transistors and a capacitor on the same substrate as that for the organic field light emitting element, an organic field light emission panel of an excellent display ability can be attained. Consequently, the organic field light emission panel of the present invention can be applied to a flat panel display (for example in a computer for OA, FA and LA, and in a wall-hanging television) and to a display panel of measuring instruments, thus providing a high technical value.

[Brief Description of the Drawings]

[Fig. 1] A schematic cross-sectional view showing an example of an organic field light emitting element to be employed in the present invention.

[Fig. 2] A circuit diagram for driving an organic field light emission panel of the present invention.

[Fig. 3] A plan view of a TFT drive circuit for an organic field light emission panel of the present invention.

[Fig. 4] An example of a TFT structure employed in the organic field light emission panel of the present invention.

[Fig. 5] An example of a manufacturing process for an organic field light emission panel of the present invention.

[Fig. 6] An input signal wave form in an example.

[Fig. 7] A pixel voltage signal wave form in an example.

[Fig. 8] A pixel light emission wave form in an example.

[Description of Symbols]

- 1 substrate
- 2 anode
- 3 positive hole transport layer
- 4 light emission layer
- 5 cathode
- 6 glass substrate
- 7a gate electrode of TFT
- 7b electrode of accumulating capacitor
- 8, 8a, 8b SiN<sub>x</sub> insulation film
- 9, 9a, 9b i-layer a-Si
- 10, 10a, 10b n<sup>+</sup> layer a-Si
- 11a source electrode
- 11b drain electrode
- 11c electrode of accumulating capacitor
- 12 ITO pixel electrode
- 13 organic light emission layer